

**C-1      STATEMENT OF WORK**

## Research and Technologies for Aerospace Propulsion Systems (RTAPS)

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# **RESEARCH AND TECHNOLOGIES FOR AEROSPACE PROPULSION SYSTEMS (RTAPS)**

## **STATEMENT OF WORK**

### **1.0 Objective**

The objective of this proposed task order contract is to develop, demonstrate, and verify advanced propulsion system technologies as part of NASA's ongoing, long-term aerospace research programs, addressing a wide variety of propulsion issues. Applications include subsonic, supersonic, hypersonic, and rotorcraft transportation vehicles, as well as aviation safety and space exploration applications.

### **2.0 Scope**

The Contractor shall furnish all personnel, facilities, equipment, material, supplies, and services, except as may be expressly set forth in the contract agreement as Government Furnished Property, and otherwise do all things necessary to, or incident to, performing and providing the work efforts set forth in the following areas. Contract scope includes analytical and experimental investigations covering a wide variety of propulsion components and sub-components having either Government, commercial, or military application. . This contract may be used to support all NASA Centers that require work within the scope of this Statement Of Work. The contractor shall perform task orders in the following technology areas:

### **2.1 RESERVED**

#### **2.2 Technology Area 2: Propulsion Airframe Integration - Airframe Systems Technology**

The contractor shall develop and demonstrate advanced propulsion-airframe integration (PAI) technologies to improve overall integrated airframe system performance, weight, emissions, safety, fuel burn, noise, life, and cost within the context of the individual project goals and objectives as defined in Appendix C-1.

The technical elements included in Technology Area 2 are as follows:

##### **2.2.1 Concept Development and Systems Studies**

The contractor shall perform concept development and system studies of nontraditional propulsion and/or vehicle arrangements and advanced aerospace systems configurations to meet NASA program goals. These concepts include unconventional airframes and engines, electric motors, alternative fuels, heat transfer devices, propulsion integration and advanced aerospace systems. System studies include performing system analyses and designs of aerospace vehicles with emphasis on propulsion systems installations to evaluate advanced technologies and aerospace system concepts that have the potential for improving system performance, weight, emissions, fuel burn, noise and costs.

The scope of work under this element includes the following:

(1) The contractor shall develop and validate empirical, statistical, and physics-based analytical models which are robust enough to handle non-conventional configurations. These models may be used for understanding the basic underlying physical phenomenon of the system or subsystem as well as for predicting aerospace systems and/or component performance, weight, emissions, reliability, life and cost.

(2) The contractor shall define goals and figures of merit for overall systems as well as for individual technologies within the context of overall program/project goals and objectives.

(3) The contractor shall conduct technology trade studies, mission analyses and market/cost scenario and life cycle environmental footprint studies to identify and evaluate aerospace systems and assess their contributions towards meeting program/project goals and objectives.

(4) The contractor shall perform system simulations of aerospace systems and subsystems from a 0-D level up through a multi-disciplinary 3-D level.

(5) The contractor shall perform aerospace systems conceptual, preliminary and/or detailed design studies in support of advanced concept definition, development and/or testing.

(6) The contractor shall conduct risk assessments of advanced aerospace systems.

#### 2.2.2 Airframe Integrated Inlets, Engines, and Exhaust Nozzles

The contractor shall investigate and develop advanced concepts to enable airframe integration of ultra-high bypass engines, propfans, embedded propulsion systems or distributed propulsion systems for subsonic applications that result in reduced fuel burn, reduced emissions, and reduced noise. The contractor shall investigate and develop integrated high performance, low sonic boom inlets and low noise nozzles for supersonic applications; and combined cycle propulsion systems for hypersonic applications. The contractor shall investigate and develop emerging technologies in this area, including: boundary-layer-ingesting (BLI) inlets, virtual shaping of the inlet lip, fore-body flow control, nacelle-wing-pylon integration, thrust vectoring nozzles, highly integrated two-dimensional (rectangular, axisymmetric) and three-dimensional inlets and nozzles, and nacelle and nozzle shaping with aircraft integration for achieving low sonic boom signatures and high installed propulsion efficiency.

The scope of work under this element includes the following:

(1) The contractor shall identify and assess advanced inlet, nozzle and PAI concepts and barrier technologies.

(2) The contractor shall develop and validate empirical, statistical, and physics-based analytical models for predicting inlet and/or nozzle component performance, thermal and mechanical loads, noise and structural integrity for both isolated and installed on the airframe or integrated with the propulsion system.

(3) The contractor shall design, develop, and test advanced inlets and nozzles concepts.

(4) The contractor shall design and develop advanced instrumentation and diagnostic systems for measurement of inlet and nozzle operating characteristics.

(5) The contractor shall develop and apply advanced composite structural concepts and supporting design, analysis, testing, and manufacturing technologies for multi-functional component applications in propulsion cases, ducts, nacelle systems, and integrated ceramic matrix composite nozzle components. Examples include; fan cases and inlet nacelles that meet structural, blade-out containment, and noise attenuation requirements in a configuration that minimizes weight and reduces part count and/or system complexity, structurally integrated thermal protection systems, and ceramic matrix composites for engine components such as nozzle flaps and seals, including, but not limited to multi-layer coatings for durable hypersonic vehicle leading edge surfaces.

(6) The contractor shall develop, design, and test advanced propulsion-airframe integration concepts

and technologies by means of ground-based and flight-based tests.

(7) The contractor shall develop advanced controls for variable geometry propulsion systems, including combined cycle and variable cycle propulsion systems.

### 2.2.3 Airframe Icing

The contractor shall perform airframe icing research and technology development to address the following challenges: accurate ice accretion simulation with emphasis on supercooled large droplets (SLD), and iced aircraft aerodynamic performance, and stability and control evaluations of both swept and unswept wing configurations.

This scope of work under this element includes the following:

(1) The contractor shall perform an assessment of advanced concepts, analytical and computational tools and barrier technologies towards understanding and preventing ice accretion or mitigating the effects of airframe icing including icing in SLD.

(2) The contractor shall develop and validate empirical, statistical, and physics-based analytical and computational models for predicting airframe icing and/or its effect on aerodynamic performance.

(3) The contractor shall design and fabricate test instrumentation and model hardware for the characterization, detection and measurement of airframe icing. Additionally, the contractor shall design and develop diagnostic systems for identifying airframe icing locations and vulnerability.

(4) The contractor shall demonstrate and evaluate airframe ice accretion and performance prediction tools, advanced airframe icing prevention and reduction concepts and technologies on component test rigs, aircraft model (subscale or full scale) tests, and flight tests.

## **2.3 RESERVED**

## **2.4 RESERVED**

## **3.0 Work Requirements**

The contractor(s) shall have the ability to perform all work in one or more of the Technology Areas as authorized in each task order issued.

The contractor(s) shall provide a program management system that includes timely insight into the technical, cost, and schedule status and risk, as well as technical and programmatic control of work performed under the task orders.

The contractor(s) shall implement a product assurance system, as appropriate, for task orders involving hardware and/or software development. The contractor's existing product assurance plans, procedures, formats, and documentation systems that support the development of safe and reliable aerospace products, are acceptable if they are shown to satisfy the objectives of the Product Assurance Requirements listed in the Product Assurance Requirements of NASA Policy Directive NPD 8730.5 NASA Quality Assurance Program Policy—URL: <http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPD&c=8730&s=5>

All work performed under this contract shall be in compliance with all applicable Federal, state, and local environmental regulations and those policies set forth in the NASA Glenn Research Center's

Environmental Programs Manual This can be viewed at: <http://smad-ext.grc.nasa.gov/shed/pub/epm/epm-manual.pdf>

Task Orders will be issued in accordance with Clause H.9-H.11.

## Appendix C–1

NASA has requirements for the development and demonstration of advanced engine technologies that will enable reductions in noise, emissions, fuel consumption, and sonic boom (high speed aircraft). Specific goals have been defined by NASA’s Subsonic Fixed Wing (SFW) and Supersonic Projects and are summarized in Tables 1 and 2, respectively. NASA’s Subsonic Rotary Wing Project has defined the goal of 50 percent variation of main rotor rotational speed needed to achieve efficient VTOL and Mach 0.5 1000 NM cruise capability, with no impact on flight handling and minimum impact to propulsion systems weight, in addition to advancing engine capabilities for future civil rotorcraft.

TABLE 1.—GOALS FOR SUBSONIC FIXED WING PROJECT

Corners of the trade space	N+1 (2015) <sup>a</sup> Generation Conventional Configurations relative to 1998 Single Aisle	N+2 (2020) <sup>a</sup> Generation Unconventional Configurations relative to 1997 Large Twin Aisle	N+3 (2025) <sup>a</sup> Generation Advanced Aircraft Concepts (relative to user-defined reference)
Noise (cum. below Stage 4)	–32 dB	–42 dB	–71dB
LTO NOx emissions (below CAEP/6)	–60%	–75%	Better than –75%
Performance: aircraft fuel burn	–33% <sup>b</sup>	–40% <sup>b</sup>	Better than –70%
Performance: field length	–33%	–50%	Exploit metro-plex concepts

<sup>a</sup>Technology Readiness Level Range = 4 to 6

<sup>b</sup> An additional reduction of 10 percent may be possible through improved operational capability.

<sup>c</sup> Concepts that enable optimal use of runways at multiple airports within the metropolitan areas.

TABLE 2.—GOALS FOR SUPERSONICS PROJECT

	N+1 Supersonic Business Class Aircraft (2015)	N+2 Small Supersonic Airline (2020)	N+3 Efficient Multi-Mach Aircraft (beyond 2030)
Environmental goals			
Sonic boom	65 to 70 PLdB	65 to 70 PLdB	65 to 70 PLdB low boom flight; 75 to 80 PldB overwater flight
Airport noise (cum. below stage 4)	Meet with margin	10 EPNdB	10 to 20 EPNdB
Cruise emissions	Equivalent to current subsonic	< 10	< 5 and particulate and water vapor mitigation
Performance goals			
Cruise speed, Mach	1.6 to 1.8	1.6 to 1.8	1.3 to 2.0
Range, nmi	4000	4000	4000 to 5500
Payload, passengers	6 to 20	35 to 70	100 to 200
Fuel efficiency, pass-miles per lb of fuel	1.0	3.0	3.5 § 4.5

Flight regime related factors include

**Subsonic:** Focus is on Ultra-High Bypass (UHB) ratio engine technologies for the N+1 goals and embedded engine and variable engine technologies for the N+2 goals, and also includes development of lower Technology Readiness Level (TRL) advanced technologies enabling propulsion systems for the N+3 time frame.

**Supersonic:** Focus is on variable cycle engine technologies for the N+2 goals and may also include development of advanced technologies enabling propulsion systems for the N+3 time frame. Some work may also be included to address N+1 system as required.

**Hypersonic:** The Hypersonic Project is developing technologies to enable reusable air-breathing access to space and to enable high mass planetary entry for Mars and other planets. For reusable air-breathing access to space technologies, the Project is aligned with the goal defined in the 2007 National Plan for Aeronautics Research, namely, to demonstrate sustained, controlled, hypersonic flight. Successful sustained, controlled, hypersonic flight requires continued R&D into all areas of high speed atmospheric flight, including integrated aircraft design, aerodynamics, aerothermodynamics, high-temperature structures and materials, lightweight and durable thermal-protection systems, supersonic combustion, and propulsion concepts that operate from subsonic speeds into the hypersonic regime. The Hypersonic Project R&D goals include extending the temperature and life of high-temperature materials and structures, reducing component mass, developing air-breathing propulsion technology for Two-Stage-to-Orbit vehicles, and developing physics-based integrated multi-disciplinary design tools.

**Rotary Wing:** Focus is on engine and transmission technologies needed for wide operability, variable speed propulsion systems (i.e. 50percent variable speed power turbine) for rotorcraft vehicles that meet performance, environmental (noise, emission), weight and cost goals that enable high speed (0.5 M), large payload (~90 passenger), long range civil transports. In addition, the Subsonic Rotary Wing Project is developing technologies to enable advanced engine capabilities for future civil rotorcraft.